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AUTHOR Bitner, Betty L.

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ABSTRACT

The purpose of this descriptive study was to investigate the developmental patterns in logical reasoning of students in grades 6-10 over a span of 20 months. The Group Assessment of Logical Thinking (GALT) was administered to the sample (N=84) during the fall of 1986, the fall of 1987, and the spring of 1988. The GALT measures six reasoning modes: conservation; proportional reasoning; controlling variables; probabilistic reasoning; correlational reasoning; and combinatorial logic. Correlational reasoning was found to be the most difficult for the total sample for the three administrations of the GALT. The results of the two-tailed t-test for gender difference were not significant. An ANOVA (GALT score by grade level) was significant for each test administration. The results seem to indicate: (1) the majority of this sample was not functioning at the formal operational reasoning level; (2) a significant movement from concrete to transitional operational reasoning occurred at the end of grade seven; and (3) a plateau effect occurred between grades eight and nine. (MVL)

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# Developmental Patterns in Logical Reasoning of Students in Grades Six through Ten: Increments and Plateaus

Betty L. Bitner

Associate Professor of

Elementary and Secondary Education

Southwest Missouri State University

Springfield, Missouri 65804

Paper presented at the annual meeting of the National Association for Research in Science Teaching, San Francisco, CA, March 30, 1989.

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**Abstract**

The purpose of this descriptive study was to investigate the developmental patterns in logical reasoning of students in grades six through ten over a span of twenty months. Gender and grade differences were also investigated. The sample (N = 84) represented a proportion of a larger rural sample of (N = 130). The Group Assessment of Logical Thinking (GALT) was administered to the sample during the fall of 1986, the fall of 1987, and the spring of 1988. The GALT measures six reasoning modes (i.e., conservation, proportional reasoning, controlling variables, probabilistic reasoning, correlational reasoning, and combinatorial logic). Cronbach's alpha reliability coefficients for the three administrations of the GALT were as follows: .78 (1986 fall), .79 (1987 fall), and .80 (1988 spring). Frequencies, percentages, means, and standard deviations were computed on all test items, the six modes of reasoning, and the total GALT scores for the three administrations of the GALT. The two-tailed t test was used to analyze gender differences on the six reasoning modes and GALT total scores. ANOVA statistic (GALT score by grade level) was used to analyze grade level differences in reasoning for the three administrations of the GALT. For the three administrations of the GALT, correlational reasoning was found to be the most difficult for the total sample. Students in grade seven (n = 17) and grade eight (n = 22) found probabilistic reasoning to be the

most difficult in the 1988 spring administration. The results of the two-tailed t test for gender differences were not significant. The ANOVA (GALT score by grade level) was significant at the .01 level for each test administration. None of the students who were first tested in grades six, seven, or nine attained formal operational reasoning as measured by the GALT. The number of students classified as formal operational reasoners for the original grade eight group remained constant throughout the three test administrations, but the number classified as transitional operational reasoners increased. For the grade ten group, a decline in the number of formal operational reasoners was found from the first test administration to the last test administration. The results seem to indicate (a) the majority of this sample was not functioning at the formal operational reasoning level, (b) a significant movement from concrete to transitional operational reasoning occurred at the end of grade seven, and (c) a plateau effect occurred between grade eight and nine.

## Theoretical Base

Formal operational reasoning as advanced by Inhelder and Piaget (1959) entails the structured whole which allows one to synthesize inversions and reciprocities in a unitary system of transformations. (p. 274) According to Inhelder and Piaget (1958), the approximate ages for development of formal operational reasoning are 12-15 years of age. Formal operational reasoning includes operational schemata based on propositional reasoning (the system of sixteen binary operations) and related to the lattice structure (combinatorial structure) and the four group transformations (Inhelder & Piaget, 1958). Inhelder and Piaget (1958) defined operational schemata "as concepts which the subject potentially can organize from the beginning of the formal level when faced with certain of data, but which are not manifest outside these conditions." (p. 308) The formal operational schemata consist of combinatorial operations, proportions, coordination of two systems of reference and the relativity of motion and acceleration, isolation of two or more variables, probability, correlation, mechanical equilibrium, multiplicative compensations, and conservation of volume (Inhelder & Piaget, 1958, 310-328). These formal operational schemata, particularly conservation of volume, begin to develop at the early formal operational stage of reasoning. The four group transformations (i.e., synthesis of inversions and reciprocities) include

Identity (I), Negation or inverse (N), Reciprocal (R), and Correlative (C), called the INRC group. Formal operational reasoning as espoused by Inhelder and Piaget (1958) is a structured whole (i.e., the mental structures of the formal operational stage develop synchronously and form a structured whole at the end of the formal operational stage).

Five formal operational modes of reasoning (i.e., proportional reasoning, controlling variables, probabilistic reasoning, correlational reasoning, and combinatorial logic) have been identified as essential for success in science and mathematics at the upper level (Capie, Newton, & Tobin, 1981; DeCarcer, Gabel, & Staver, 1978; Lawson, 1985).

In a study of students in grades six through twelve, Bitner (in review) reported a dramatic increase in the proportion of formal operational reasoners between grade 9 (3%) and grade 10 (28%). She also found the greatest increase from concrete to transitional operation between seventh and eighth grade.

In their use of the GALT, Atwater (1988), Bitner (1986, 1987), and Mattheis (1988) found no gender differences.

The primary purpose of this descriptive-developmental study was to investigate the developmental reasoning patterns of students in grades six through ten over a span of twenty months. Gender and grade differences in logical thinking were also investigated.

## Method

### Sample

The sample (N = 84) for this study of developmental patterns in logical reasoning of students beginning in grades six through ten represented a proportion (65%) of a larger rural sample of a rural Arkansas consolidated school district (N = 130). Mainstreamed students were included in the sample. The student enrollment K-12 was approximately 350; the socioeconomic level of the district is considered low to poverty because of the preponderance of students qualifying for free lunch. The mean age, standard deviation, and age range of subjects at each grade were as follows: (a) grade 6 (8 males and 9 females, M = 11.88, SD = .52, Range = 10.97 - 13.00); (b) grade 7 (10 males and 12 females, M = 12.93, SD = .56, Range = 11.92 - 14.42); (c) grade 8 (9 males and 8 females, M = 13.50, SD = .76, Range = 12.00 - 14.42); (d) grade 9 (7 males and 5 females, M = 14.68, SD = .42, Range = 14.08 - 15.67); and (e) grade 10 (8 males and 8 females, M = 15.32, SD = .44, Range = 14.42 - 16.08).

In addition to the curricula mandated by the new Arkansas Education Standards, the teachers were expected to implement higher order thinking skills (i.e., critical, logical, and creative thinking processes) into their curricula.

## Instrumentation

The instruments administered in this study were the twelve item abbreviated GALT or the twenty-one item GALT (Roadrangka, Yeany, & Padilla, 1982). The results of the validation study indicated a coefficient alpha of .85 for the twenty-one item GALT and .80 correlation coefficient between the GALT and the Piagetian interview tasks (Roadrangka, Yeany, & Padilla, 1983). Both forms of the GALT measure one concrete-transitional operational reasoning mode (i.e., conservation of mass and volume) and five formal operational reasoning modes (i.e., controlling variables, proportional reasoning, probabilistic reasoning, correlational reasoning, and combinatorial logic). The GALT was selected over other instruments of logical thinking for the following reasons: (a) Except for the three supply-type items (19, 20, and 21), it is a multiple-choice paper and pencil test. (b) Specific scoring procedures and test format increase the test's reliability. (c) It measures six logical operations including correlational reasoning as identified by Inhelder and Piaget (1958).

To receive credit for the first eighteen items on the GALT, one must select both the correct response and correct justification. Credit for items 19, 20, and 21 is given for acceptable combinatorial logic patterns. Classification of students according to reasoning levels on the twelve-item abbreviated GALT is as follows: (a) 8-12, formal; (b) 5-7, transitional; and (c) 0-4, concrete. On the total GALT, the

reasoning level classification is as follows: (a) 16-21, formal; (b) 9-15, transitional; and (c) 0-8, concrete.

The abbreviated GALT was administered to the sample in the fall of 1986; the twenty-one item GALT was administered to the same sample in the fall of 1987 and spring of 1988.

**Results**

Cronbach's alpha correlation coefficients for the three administrations of the GALT were as follows: .78 (fall 1986), .79 (fall 1987), and .80 (spring 1988).

The means and standard deviations from least to most difficult per reasoning mode and total score on the abbreviated GALT for the sample (N = 84) in the fall of 1986 were as follows: (a) conservation (M = 1.17, SD = .73); (b) combinatorial logic (M = .58, SD = .66); (c) controlling variables (M = .54, SD = .72); (d) proportional reasoning (M = .33, SD = .33); (e) probabilistic reasoning (M =.27, SD = .65); (f) correlational reasoning (M = .16, SD = .43); and total score (M = 3.06, SD = 2.57). These students were in grades six through ten.

As reported in Table 1 the means and standard deviations from least to most difficult per reasoning mode and total score for the sixth grade group (n = 17) were as follows: (a) conservation (M = .94), SD = .75); (b) combinatorial logic (M = .47, SD = .51); (c) controlling variables and probabilistic reasoning (M = .18, SD = .39);

(d) proportional reasoning and correlational reasoning (M = .06, SD = .39); and (e) total score (M = 1.88, SD =1.32).

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Insert Table 1 about here

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For the students in grade seven (n = 22), the means and standard deviations from least to most difficult per reasoning mode and total score were as follows: (a) conservation (M = .82, SD = .73); (b) combinatorial logic (M = .32, SD = .48); (c) controlling variables (M = .27, SD = .63); (d) proportional reasoning and correlational reasoning (M = .09, SD = .29); (e) probabilistic reasoning (M = .09, SD = .43); and (f) total score (M = 1.68, SD = 1.70) (see Table 2).

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Insert Table 2 about here

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The grade eight students (n = 17) had means and standard deviations (see Table 3) from least to most difficult per reasoning mode and total score as follows: (a) conservation (M = 1.29, SD = .69); (b) combinatorial logic (M = .77, SD = .75); (c) controlling variables (M = .71, SD = .77); (d) probabilistic reasoning (M = .29, SD = .69); (e) correlational reasoning (M = .24), SD = .56); (f) proportional reasoning (M = .12, SD = .33); and (g) total score (M = 3.47, SD = 2.45).

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Insert Table 3 about here

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For the students in grade nine (n = 12), the means and standard deviations from least to most difficult per reasoning mode and total score were as follows as reported in Table 4: (a) conservation (M = 1.58, SD = .52); (b) controlling variables (M = .58, SD = .67); (c) proportional reasoning (M = .58, SD = .79); (d) combinatorial logic (M = .42, SD = .52); (e) probabilistic reasoning (M = .17, SD = .58); (f) correlational reasoning (M = .00, SD =.00); and (g) total score (M = 3.33, SD = 1.56).

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Insert Table 4 about here

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As reported in Table 5, the means and standard deviations from least to most difficult per reasoning mode and total score for students in grade ten (n = 16) were as follows: (a) conservation (M = 1.44, SD = .68); (b) controlling variables (M = 1.06, SD = .77); (c) proportional reasoning and combinatorial logic (M = 1.00, SD = .82); (d) probabilistic reasoning (M = .69, SD = .95); (e) correlational reasoning (M = .38, SD = .62); and (f) total score (M = 5.56, SD = 3.33).

Insert Table 5 about here

The means and standard deviations from least to most difficult per reasoning mode and total score on the total GALT for the sample (N = 84) in the fall of 1987 were as follows: (a) conservation (M = 1.20, SD = 1.30); (b) proportional reasoning (M = 2.93, SD = 1.50); (c) controlling variables (M = 1.20, SD = .98); (d) combinatorial logic (M = .83, SD = .79); (e) probabilistic reasoning (M = .42, SD = .78); (f) correlational reasoning (M = .26, SD = .52); and total score (M = 6.92, SD = 3.79). These students were beginning grades seven through eleven.

As reported in Table 1, the students in grade seven (n = 17) had means and standard deviations from least to most difficult per reasoning mode and total score as follows: (a) conservation (M = 2.65, SD = 1.27); (b) combinatorial logic (M = 1.00, SD = .87); (c) controlling variables (M = .71, SD = 1.10); (d) proportional reasoning (M = .59, SD = .71); (e) correlational reasoning (M = .12, SD = .33); (f) probabilistic reasoning (M = .06, SD = .24); and (g) total score (M = 5.12, SD = 2.47). The means and standard deviations from least to most difficult per reasoning mode and total score for the students in grade eight (n = 22) were as follows (see Table 2): (a) conservation (M = 2.68, SD = 1.04); (b) proportional reasoning (M =

.96, SD = 1.50): (c) controlling variables (M = .77, SD = .97); (d) combinatorial logic (M = .59, SD = .73); (e) correlational reasoning (M = .23, SD = .43); (f) probabilistic reasoning (M = .09, SD = .43); and (g) total score (M = 5.41, SD = 2.84). For the students in grade nine (n = 17), means and standard deviations reported in Table 3 from least to most difficult per reasoning mode and total score were as follows: (a) conservation (M = 3.35, SD = .79(; (b) controlling variables (M = 1.29, SD = 1.45); (c) proportional reasoning (M = 1.29, SD = 1.45); (d) combinatorial logic (M = .59, SD = .62); (e) probabilistic reasoning (M = .59, SD = .87); and (f) correlational reasoning (M =.29; SD = .59); and (g) total score (M = 7.41, SD = .50). The students in grade ten (n = 12) had means and standard deviations as reported in Table 4 from least to most difficult per reasoning mode and total score as follows: (a) conservation (M = 3.00, SD = .60); (b) controlling variables (M = 1.50, SD = 1.45); (c) proportional reasoning (M = 1.25, SD = .75); (d) combinatorial logic (M = .83, SD =.72); (e) probabilistic reasoning (M = .67, SD = .72); (f) correlational reasoning (M = .25; SD = .45); and (g) total score (M = 7.50, SD = 2.39). As reported in Table 5, those students in grade eleven (n = 16) had means and standard deviations from least to most difficult per reasoning mode and total score as follows: (a) conservation (M = 3.06, SD = .85; (b) proportional reasoning (M = 2.31, SD = 2.06); (c) controlling variables (M = 2.00, SD = 1.46); (d)

combinatorial logic (M = 1.25, SD = .86); (e) probabilistic reasoning (M = .88, SD = 1.03); (f) correlational reasoning (M = .44, SD = .73); and (g) total score (M = 9.94, SD = 5.18).

The means and standard deviation form least to most difficult per reasoning mode and total score on the total GALT for the sample (N = 84) in the spring of 1988 were as follows: (a) conservation (M = 2.76, SD = 1.01); (b) controlling variables (M = 1.57, SD = 1.51); (c) proportional reasoning (M = 1.36, SD = 1.72); (d) probabilistic reasoning (M = .57, SD = .90); (e) combinatorial logic (M = .46, SD = .50); (f) correlational reasoning (M = .25, SD = .46); and total score (M = 6.92, SD = 4.32). These students were finishing grades seven through eleven.

The means and standard deviations from least to most difficult per reasoning mode and total score for students at the end of seventh grade (n = 17) were as follows: (a) conservation (M = 2.71, SD = .92); (b) controlling variables (M = .82, SD = 1.33); (c) combinatorial logic (M = .35, SD =.49); (d) proportional reasoning (M = .29, SD = .47); (e) correlational reasoning (M = .18, SD = .39); (f) probabilistic reasoning (M = .00, SD = .00); and (g) total score (M = 4.47, SD = 1.81). For students at the end of grade eight (n = 22), the means and standard deviations from least to most difficult per reasoning mode and total score were as follows: (a) conservation (M = 2.46, SD = 1.01); (b) controlling variables (M =1.27, SD = 1.32); (c) proportional

reasoning (M = 1.09, SD = 1.74); (d) combinatorial logic (M = .41, SD = .50); (e) correlational reasoning (M = .18, SD = .40); (f) probabilistic reasoning (M = .18, SD = .50); and (g) total score (M = 5.55, SD = 3.93). Those students at the end of ninth grade (n = 17) had means and standards deviations from least to most difficult per reasoning mode and total score as follows: (a) conservation (M = 3.24, SD = .97); (b) controlling variables (M = 2.24, SD = 1.56); (c) proportional reasoning (M = 1.82, SD = 1.78); (d) probabilistic reasoning (M = 1.12, SD = .99); (e) combinatorial logic (M = .53, SD = .51); (f) correlational reasoning (M = .41, SD = .51); and (g) total score (M = 9.29, SD = 4.21). The means and standard deviations from least to most difficult per reasoning mode and total score for the students at the end of tenth grade (n = 12) were as follows: (a) conservation (M = 3.00, SD = .60); (b) controlling variables (M = 2.17, SD = 1.34); (c) proportional reasoning (M = 1.75, SD = 1.60); (d) probabilistic reasoning (M = .92, SD = 1.17); (e) combinatorial logic (M = .42, SD = .52); (f) correlational reasoning (M = .17, SD = .39); and (g) total score (M = 8.25, SD = 3.52. For the students at the end of grade eleven (n = 16), the means and standard deviations from least to most difficult per reasoning mode were as follows: (a) conservation (M = 2.53, SD = 1.25); (b) proportional reasoning (M = 2.13, SD = 2.07); (c) controlling variables (M = 1.60, SD = 1.68); (d) probabilistic reasoning (M =

.87, SD = .99); (e) combinatorial logic (M = .63, SD = .50); (f) correlational reasoning (M = .31, SD = .60); and (g) total score (M = 7.88, SD = 5.64).

The frequencies and percentages according to reasoning levels for those students first tested in grade six (n = 17) were as follows: (a) 1986: 17 (100%) concrete operational; (b) 1987: 2 (12%) transitional operational and 15 (88%) concrete operational; and (c) 1988: 1 (6%) transitional and 16 (94%) concrete operational (see Table 6).

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Insert Table 6 about here

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The frequencies and percentages according to reasoning levels for those students first tested in grade seven (n = 22) were as follows: (a) 1986: 1 (5%) transitional operational and 21 (95%) concrete operational; (b) 1987: 3 (14%) transitional operational and 19 (86%) concrete operational; and (c) 20 (91%) transitional operational and 2 (9%) concrete operational (see Table 7).

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Insert Table 7 about here

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The frequencies and percentages according to reasoning levels for those students first tested in grade eight (n = 17) were as follows: (a) 1986: 1 (6%) formal, 5 (29%) transitional, and 11 (65%) concrete; (b) 1987: 5 (29%) transitional and 12 (71%) concrete; (c) 1988: 1 (6%) formal, 6 (35%) transitional, and 10 (59%) concrete (see Table 8 about here).

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Insert Table 8 about here

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The frequencies and percentages according to reasoning levels for those students first test in grade nine (n = 12) were as follows: (a) 1986: 2 (17%) transitional and 10 (83%) concrete; (b) 1987: 6 (50%) transitional and 6 (50%) concrete; c) 5 (42%) transitional and 7 (58%) concrete (see Table 9).

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Insert Table 9 about here

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The frequencies and percentages according to reasoning levels for those students first tested in grade ten (n =16) were as follows: (a) 1986: 4 (25%) formal, 5 (31%) transitional, and 7 (44%) concrete; (b) 1987: 3 (19%) formal, 6 (38% transitional, and 7 (44%); (c) 1988: 1 (6%) formal, 6 (38%) transitional, and 9 (56%) concrete (see Table 10).

Insert Table 10 about here

The two-tailed t test analyses for gender differences in the six modes of reasoning on the GALT for the three test administrations were not significant at the .01 level. However, in each administration of the GALT the males scored higher than the females.

The analyses of variance (GALT by grade level) indicated significant grade differences: (a) 1986 (grade ten, $n = 16$): $F(4,79) = 42.33$, $p < .01$; (b) 1987 (grade eleven, $n = 16$): $F(4,79) = 4.27$, $p < .01$; and 1988 (grade eight, $n = 17$): $F(4,79) = 4.27$, $p < .01$.

## Conclusions

For the three administrations of the GALT, correlational reasoning was found to be the most difficult for the total sample. In addition, correlational reasoning was found to be the most difficult for each grade level for the three administrations of the test except for two grade levels during the 1988 administration. For those in grade seven ($n = 17$) and grade eight ($n = 22$), probabilistic reasoning followed by correlational reasoning was the most difficult.

None of the students first tested in grade six ($n = 17$) or in grade seven ($n = 22$) attained formal operational reasoning on the GALT, but the number of those classified as transitional operational increased. Of those students first tested in grade ($n = 17$), the

frequency and percentage (1, 6%) of formal operational reasoners remained the same from 1986 to 1988, but number of transitional operational reasoners increased one percent. None of the students first tested in grade nine (n = 12) attained formal operational reasoning as measured by the GALT. However, the number classified as transitional operational thinkers increased. Increases in the number classified as transitional operational and decreases in the number classified as concrete operational were found for the grade ten group (n = 16). An unexpected result was the decline in those students classified as formal operational reasoners from the first test administration to the last test administration.

Significant gender difference were not found. However, grade level of the student was found to be significant.

The results of this study seem to indicate that the majority of students in grades six through eleven are not functioning at the formal operational level as measured by the GALT. Also, the findings seem to suggest the following: (a) a significant movement from concrete to transitional operational occurs at the end of grade seven and (b) a plateau effect occurs between grade eight and nine.

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**Table 1**

**Mean and Standard Deviation on the GALT for Students First Tested in Grade Six (N = 17)**

| Reasoning Skill | Test Administration | | | | | |
|---|---|---|---|---|---|---|
| | 1986 (Grade 6) | | 1987 (Grade 7) | | 1988 (End of Grade 7) | |
| | M | SD | M | SD | M | SD |
| **Conservation** | .94 | .75 | 2.65 | 1.27 | 2.71 | .92 |
| Item 1 | .65 | .49 | .71 | .47 | .82 | .39 |
| Item 2 | | | .82 | .39 | .77 | .44 |
| Item 3 | .71 | .47 | .82 | .39 | | |
| Item 4 | .35 | .49 | .41 | .51 | .47 | .51 |
| **Proportionality** | .06 | .24 | .59 | .71 | .29 | .47 |
| Item 5 | | | .06 | .24 | .00 | .00 |
| Item 6 | | | .06 | .24 | .00 | .00 |
| Item 7 | | | .12 | .33 | .00 | .00 |
| Item 8 | .00 | .00 | .00 | .00 | .00 | .00 |
| Item 9 | .06 | .24 | .24 | .44 | .00 | .00 |
| Item 10 | | | .12 | .33 | .06 | .24 |
| **Controlling Variables** | .18 | .39 | .71 | 1.10 | .82 | 1.33 |
| Item 11 | .12 | .33 | .18 | .39 | .24 | .44 |
| Item 12 | | | .18 | .39 | .18 | .39 |
| Item 13 | .06 | .24 | .24 | .44 | .29 | .47 |
| Item 14 | | | .12 | .33 | .06 | .24 |
| **Probability** | .18 | .39 | .06 | .24 | .00 | .00 |
| Item 15 | .12 | .33 | .00 | .00 | .00 | .00 |
| Item 16 | .06 | .24 | .06 | .24 | .00 | .00 |
| **Correlational** | .06 | .24 | .12 | .33 | .18 | .39 |
| Item 17 | .06 | .24 | .00 | .00 | .18 | .39 |
| Item 18 | .00 | .00 | .12 | .33 | .00 | .00 |
| **Combinatorial** | .47 | .51 | 1.00 | .87 | .35 | .49 |
| Item 19 | .35 | .49 | .59 | .51 | .41 | .51 |
| Item 20 | .12 | .33 | .41 | .51 | .00 | .00 |
| Item 21 | | | .00 | .00 | .00 | .00 |
| **GALT Total** | 1.88 | 1.32 | 5.12 | 2.47 | 4.47 | 1.81 |

Note. The points possible for the 1986 administration are twelve. The total points possible for the 1987 and 1988 administration are twenty-one.

**Table 2**

**Mean and Standard Deviation on the GALT for Students First Tested in Grade Seven (N = 22)**

| Reasoning Skill | Test Administration | | | | | |
|---|---|---|---|---|---|---|
| | 1986 (Grade 7) | | 1987 (Grade 8) | | 1988 (End of Grade 8) | |
| | M | SD | M | SD | M | SD |
| **Conservation** | .82 | .73 | 2.68 | 1.04 | 2.46 | 1.01 |
| Item 1 | .55 | .51 | .73 | .46 | .68 | .48 |
| Item 2 | | | .91 | .29 | 1.23 | 1.77 |
| Item 3 | | | .50 | .51 | .46 | .51 |
| Item 4 | .27 | .46 | .59 | .50 | .50 | .51 |
| **Proportionality** | .09 | .29 | .96 | 1.50 | 1.09 | 1.74 |
| Item 5 | | | .09 | .29 | .14 | .35 |
| Item 6 | | | .14 | .35 | .18 | .40 |
| Item 7 | | | .05 | .21 | .18 | .40 |
| Item 8 | .00 | .00 | .09 | .29 | .18 | .40 |
| Item 9 | .09 | .29 | .18 | .40 | .32 | .48 |
| Item 10 | .00 | .00 | .32 | .48 | .14 | .35 |
| **Controlling Variables** | .27 | .63 | .77 | .97 | 1.27 | 1.32 |
| Item 11 | .14 | .35 | .23 | .43 | .36 | .49 |
| Item 12 | | | .23 | .43 | .32 | .48 |
| Item 13 | .14 | .35 | .36 | .49 | .27 | .46 |
| Item 14 | | | .09 | .29 | .32 | .48 |
| **Probability** | .09 | .43 | .09 | .43 | .18 | .50 |
| Item 15 | .05 | .21 | .05 | .21 | .09 | .29 |
| Item 16 | .05 | .21 | .05 | .21 | .18 | .40 |
| **Correlational** | .09 | .29 | .23 | .43 | .18 | .40 |
| Item 17 | .09 | .29 | .09 | .29 | .09 | .29 |
| Item 18 | .00 | .00 | .14 | .35 | .05 | .21 |
| **Combinatorial** | .32 | .48 | .59 | .73 | .41 | .50 |
| Item 19 | .32 | .48 | .36 | .49 | .41 | .50 |
| Item 20 | .00 | .00 | .23 | .43 | .00 | .00 |
| Item 21 | | | .23 | .43 | .00 | .00 |
| **GALT Total** | 1.68 | 1.70 | 5.41 | 2.84 | 5.55 | 3.93 |

**Note.** The points possible for the 1986 administration are twelve. The total points possible for the 1987 and 1988 administration are twenty-one.

**Table 3**

**Mean and Standard Deviation on the GALT for Students First Tested in Grade Eight (N = 17)**

| Reasoning Skill | Test Administration | | | | | |
|---|---|---|---|---|---|---|
| | 1986 (Grade 8) | | 1987 (Grade 9) | | 1988 (End of Grade 9) | |
| | M | SD | M | SD | M | SD |
| **Conservation** | 1.29 | .69 | 3.35 | .79 | 3.24 | .97 |
| Item 1 | .88 | .33 | .94 | .24 | .94 | .24 |
| Item 2 | | | .94 | .24 | .94 | .24 |
| Item 3 | | | .82 | .39 | .59 | .51 |
| Item 4 | .47 | .51 | .65 | .49 | .77 | .44 |
| **Proportionality** | .12 | .33 | 1.29 | 1.45 | 1.82 | 1.78 |
| Item 5 | | | .06 | .24 | .24 | .44 |
| Item 6 | | | .12 | .33 | .29 | .47 |
| Item 7 | | | .18 | .39 | .41 | .51 |
| Item 8 | .00 | .00 | .24 | .44 | .24 | .44 |
| Item 9 | .12 | .33 | .41 | .51 | .29 | .47 |
| Item 10 | | | .29 | .47 | .35 | .49 |
| **Controlling Variables** | .71 | .77 | 1.29 | 1.26 | 2.24 | 1.56 |
| Item 11 | .41 | .51 | .41 | .51 | .59 | .51 |
| Item 12 | | | .47 | .51 | .71 | .47 |
| Item 13 | .29 | .47 | .29 | .47 | .47 | .51 |
| Item 14 | | | .12 | .33 | .47 | .51 |
| **Probability** | .29 | .69 | .59 | .87 | 1.12 | .99 |
| Item 15 | .12 | .33 | .24 | .44 | .59 | .51 |
| Item 16 | .18 | .39 | .35 | .49 | .53 | .51 |
| **Correlational** | .24 | .56 | .29 | .59 | .41 | .51 |
| Item 17 | .18 | .39 | .24 | .44 | .35 | .49 |
| Item 18 | .06 | .24 | .06 | .24 | .00 | .00 |
| **Combinatorial** | .77 | .75 | .59 | .62 | .53 | .51 |
| Item 19 | .59 | .51 | .53 | .51 | .53 | .51 |
| Item 20 | .18 | .39 | .06 | .24 | .00 | .00 |
| Item 21 | | | .00 | .00 | .00 | .00 |
| **GALT Total** | 3.47 | 2.45 | 7.41 | 3.50 | 9.29 | 4.21 |

Note. The points possible for the 1986 administration are twelve. The total points possible for the 1987 and 1988 administration are twenty-one.

**Table 4**

**Mean and Standard Deviation on the GALT for Students First Tested in Grade Nine (N = 12)**

| Reasoning Skill | Test Administration | | | | | |
|---|---|---|---|---|---|---|
| | 1986 (Grade 9) | | 1987 (Grade 10) | | 1988 (End of Grade 10) | |
| | M | SD | M | SD | M | SD |
| **Conservation** | 1.58 | .52 | 3.00 | .60 | 3.00 | .60 |
| Item 1 | 1.00 | .00 | .92 | .29 | 1.00 | .00 |
| Item 2 | | | .92 | .29 | 1.00 | .00 |
| Item 3 | | | .42 | .52 | .08 | .29 |
| Item 4 | .58 | .52 | .75 | .45 | .75 | .45 |
| **Proportionality** | .58 | .79 | 1.25 | .75 | 1.75 | 1.60 |
| Item 5 | | | .00 | .00 | .17 | .39 |
| Item 6 | | | .00 | .00 | .08 | .29 |
| Item 7 | | | .17 | .39 | .25 | .45 |
| Item 8 | .17 | .39 | .17 | .39 | .42 | .52 |
| Item 9 | .42 | .52 | .50 | .52 | .42 | .52 |
| Item 10 | | | .42 | .52 | .50 | .52 |
| **Controlling Variables** | .58 | .67 | 1.50 | 1.45 | 2.17 | 1.34 |
| Item 11 | .33 | .49 | .42 | .52 | .75 | .45 |
| Item 12 | | | .50 | .52 | .75 | .45 |
| Item 13 | .25 | .45 | .50 | .52 | .42 | .52 |
| Item 14 | | | .17 | .39 | .25 | .45 |
| **Probability** | .17 | .58 | .67 | .89 | .92 | 1.17 |
| Item 15 | .08 | .29 | .25 | .45 | .50 | .52 |
| Item 16 | .08 | .29 | .33 | .49 | .50 | .52 |
| **Correlational** | .00 | .00 | .25 | .45 | .17 | .39 |
| Item 17 | .00 | .00 | .17 | .39 | .08 | .29 |
| Item 18 | .00 | .00 | .08 | .29 | .08 | .29 |
| **Combinatorial** | .42 | .52 | .83 | .72 | .42 | .52 |
| Item 19 | .17 | .39 | .33 | .49 | .42 | .52 |
| Item 20 | .25 | .45 | .50 | .52 | .00 | .00 |
| Item 21 | | | .00 | .00 | .00 | .00 |
| **GALT Total** | 3.33 | 1.56 | 7.50 | 2.39 | 8.25 | 3.52 |

Note. The points possible for the 1986 administration are twelve. The total points possible for the 1987 and 1988 administration are twenty-one.

**Table 5**

**Mean and Standard Deviation on the GALT for Students First Tested in Grade Ten (N = 16)**

| Reasoning Skill | Test Administration | | | | | |
|---|---|---|---|---|---|---|
| | 1986 (Grade 10) | | 1987 (Grade 11) | | 1988 (End of Grade 11) | |
| | M | SD | M | SD | M | SD |
| **Conservation** | 1.44 | .68 | 3.06 | .85 | 2.53 | 1.25 |
| Item 1 | .94 | .25 | .94 | .25 | .87 | .24 |
| Item 2 | | | .88 | .34 | .81 | .40 |
| Item 3 | | | .69 | .48 | .63 | .50 |
| Item 4 | .50 | .52 | .56 | .51 | .38 | .50 |
| **Proportionality** | 1.00 | .82 | 2.31 | 2.06 | 2.13 | 2.07 |
| Item 5 | | | .31 | .48 | .19 | .40 |
| Item 6 | | | .25 | .45 | .13 | .34 |
| Item 7 | | | .31 | .48 | .44 | .51 |
| Item 8 | .50 | .52 | .44 | .51 | .50 | .52 |
| Item 9 | .50 | .52 | .56 | .51 | .44 | .51 |
| Item 10 | | | .44 | .51 | .31 | .48 |
| **Controlling Variables** | 1.06 | .77 | 2.00 | 1.46 | 1.60 | 1.68 |
| Item 11 | .63 | .50 | .56 | .51 | .38 | .50 |
| Item 12 | | | .56 | .51 | .25 | .45 |
| Item 13 | .44 | .51 | .56 | .51 | .44 | .51 |
| Item 14 | | | .31 | .48 | .38 | .50 |
| **Probability** | .69 | .95 | .88 | 1.03 | .87 | .99 |
| Item 15 | .38 | .50 | .44 | .51 | .38 | .50 |
| Item 16 | .31 | .48 | .43 | .51 | .44 | .51 |
| **Correlational** | .38 | .62 | .44 | .73 | .31 | .60 |
| Item 17 | .31 | .48 | .31 | .48 | .25 | .45 |
| Item 18 | .06 | .25 | .13 | .34 | .06 | .25 |
| **Combinatorial** | 1.00 | .82 | 1.25 | .86 | .63 | .50 |
| Item 19 | .69 | .48 | .63 | .50 | .63 | .50 |
| Item 20 | .31 | .48 | .63 | .50 | .00 | .00 |
| Item 21 | | | .00 | .00 | .00 | .00 |
| **GALT Total** | 5.56 | 3.33 | 9.94 | 5.18 | 7.88 | 5.64 |

Note. The points possible for the 1986 administration are twelve. The total points possible for the 1987 and 1988 administration are twenty-one.

**Table 6**

**Levels of Reasoning on the GALT for Students First Tested in Grade Six**

**(N = 17)**

| | | Reasoning Level | | | | | |
|---|---|---|---|---|---|---|---|
| | | Formal[a] | | Transitional[b] | | Concrete[c] | |
| | | N | % | N | % | N | % |
| 1986 | (N = 17) | 0 | 0% | 0 | 0% | 17 | 100% |
| Male | (N = 8) | 0 | 0% | 0 | 0% | 8 | 100% |
| Female | (N = 9) | 0 | 0% | 0 | 0% | 9 | 100% |
| 1987 | (N = 17) | 0 | 0% | 2 | 12% | 15 | 88% |
| Male | (N = 8) | 0 | 0% | 1 | 13% | 7 | 88% |
| Female | (N = 9) | 0 | 0% | 1 | 11% | 8 | 89% |
| 1988 | (N = 17) | 0 | 0% | 1 | 6% | 16 | 94% |
| Male | (N = 8) | 0 | 0% | 0 | 0% | 8 | 100% |
| Female | (N = 9) | 0 | 0% | 1 | 11% | 8 | 89% |

[a] Twenty-one item GALT: 16-21; Twelve item GALT: 8-12.

[b] Twenty-one item GALT: 9-15; Twelve item GALT: 5-7.

[c] Twenty-one item GALT: 0-8; Twelve item GALT: 0-4.

**Table 7**

**Levels of Reasoning on the GALT for Students First Tested in Grade Seven (N = 22)**

| | | Reasoning Level | | | | | |
|---|---|---|---|---|---|---|---|
| | | Formal[a] | | Transitional[b] | | Concrete[c] | |
| | | N | % | N | % | N | % |
| 1986 | (N = 22) | 0 | 0% | 1 | 5% | 21 | 95% |
| Male | (N = 10) | 0 | 0% | 0 | 0% | 10 | 100% |
| Female | (N = 12) | 0 | 0% | 1 | 8% | 11 | 92% |
| 1987 | (N = 22) | 0 | 0% | 3 | 14% | 19 | 86% |
| Male | (N = 10) | 0 | 0% | 2 | 20% | 8 | 80% |
| Female | (N = 12) | 0 | 0% | 1 | 8% | 11 | 92% |
| 1988 | (N = 22) | 0 | 0% | 20 | 91% | 2 | 9% |
| Male | (N = 10) | 0 | 0% | 1 | 10% | 9 | 90% |
| Female | (N = 12) | 0 | 0% | 1 | 8% | 11 | 92% |

[a] Twenty-one item GALT: 16-21; Twelve item GALT: 8-12.

[b] Twenty-one item GALT: 9-15; Twelve item GALT: 5-7.

[c] Twenty-one item GALT: 0-8; Twelve item GALT: 0-4.

**Table 8**

**Levels of Reasoning on the GALT for Students First Tested in Grade Eight (N = 17)**

| | | Reasoning Level | | | | | |
|---|---|---|---|---|---|---|---|
| | | Formal[a] | | Transitional[b] | | Concrete[c] | |
| | | N | % | N | % | N | % |
| 1986 | (N = 17) | 1 | 6% | 1 | 29% | 11 | 65% |
| Male | (N = 9) | 1 | 11% | 3 | 33% | 5 | 56% |
| Female | (N = 8) | 0 | 0% | 2 | 25% | 6 | 75% |
| 1987 | (N = 17) | 0 | 0% | 5 | 29% | 12 | 71% |
| Male | (N = 9) | 0 | 0% | 4 | 44% | 5 | 56% |
| Female | (N = 8) | 0 | 0% | 1 | 13% | 7 | 88% |
| 1988 | (N = 17) | 1 | 6% | 6 | 35% | 10 | 59% |
| Male | (N = 9) | 1 | 11% | 5 | 56% | 3 | 33% |
| Female | (N = 8) | 0 | 0% | 1 | 13% | 7 | 88% |

[a] Twenty-one item GALT: 16-21; Twelve item GALT: 8-12.

[b] Twenty-one item GALT: 9-15; Twelve item GALT: 5-7.

[c] Twenty-one item GALT: 0-8; Twelve item GALT: 0-4.

**Table 9**

**Levels of Reasoning on the GALT for Students First Tested in Grade Nine (N = 12)**

| | | Reasoning Level | | | | | |
|---|---|---|---|---|---|---|---|
| | | Formal[a] | | Transitional[b] | | Concrete[c] | |
| | | N | % | N | % | N | % |
| 1986 | (N = 12) | 0 | 0% | 2 | 17% | 10 | 83% |
| Male | (N = 7) | 0 | 0% | 1 | 14% | 6 | 86% |
| Female | (N = 5) | 0 | 0% | 1 | 20% | 4 | 80% |
| 1987 | (N = 12) | 0 | 0% | 6 | 50% | 6 | 50% |
| Male | (N = 7) | 0 | 0% | 4 | 57% | 3 | 43% |
| Female | (N = 5) | 0 | 0% | 2 | 40% | 3 | 60% |
| 1988 | (N = 12) | 0 | 0% | 5 | 42% | 7 | 58% |
| Male | (N = 7) | 0 | 0% | 4 | 57% | 3 | 43% |
| Female | (N = 5) | 0 | 0% | 1 | 20% | 7 | 80% |

[a] Twenty-one item GALT: 16-21; Twelve item GALT: 8-12.

[b] Twenty-one item GALT: 9-15; Twelve item GALT: 5-7.

[c] Twenty-one item GALT: 0-8; Twelve item GALT: 0-4.

**Table 10**

**Levels of Reasoning on the GALT for Students First Tested in Grade Ten (N = 16)**

| | | Reasoning Level | | | | | |
|---|---|---|---|---|---|---|---|
| | | Formal[a] | | Transitional[b] | | Concrete[c] | |
| | | N | % | N | % | N | % |
| 1986 | (N = 16) | 4 | 25% | 5 | 31% | 7 | 44% |
| Male | (N = 8) | 2 | 25% | 3 | 38% | 3 | 38% |
| Female | (N = 8) | 2 | 25% | 2 | 25% | 4 | 50% |
| 1987 | (N = 16) | 3 | 19% | 6 | 38% | 7 | 44% |
| Male | (N = 8) | 2 | 25% | 4 | 50% | 2 | 25% |
| Female | (N = 8) | 1 | 13% | 2 | 25% | 5 | 63% |
| 1988 | (N = 16) | 1 | 6% | 6 | 38% | 9 | 56% |
| Male | (N = 8) | 1 | 13% | 2 | 25% | 5 | 63% |
| Female | (N = 8) | 0 | 0% | 4 | 50% | 4 | 50% |

[a] Twenty-one item GALT: 16-21; Twelve item GALT: 8-12.

[b] Twenty-one item GALT: 9-15; Twelve item GALT: 5-7.

[c] Twenty-one item GALT: 0-8; Twelve item GALT: 0-4.